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(54) Recording medium.

(57) There is provided an information memory medium comprising a memory layer composed of liquid crystal having molecules and a polymer member having minute pores in which the liquid crystal is contained causing the liquid crystal having a threshold potential thereby the molecules of the liquid crystal respond to be oriented only when an applied electric field is over the threshold potential, and the molecules thus oriented are maintained after the applied electric field is removed.

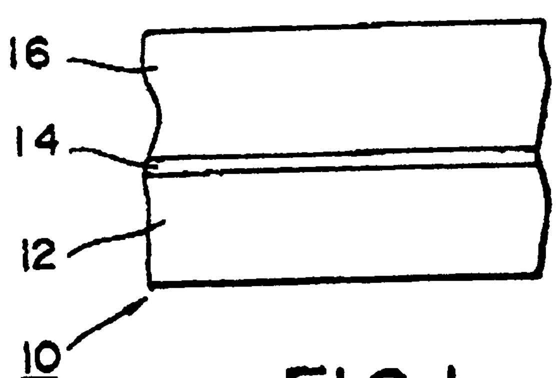

FIG. 1

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BACKGROUND OF THE INVENTION

The present invention relates to a recording medium for storing a charge image.

With increasing demands for recording signals carrying various information of high recording density, recording media manufactured based on various structural or operational principles have been used for high density-recording/reproduction.

There is a phase change-type recording medium as for the recording medium in which signals carrying information are recorded thereon by irradiating a recording layer thereof with a beam which is intensity-modulated by the signals to produce physical or chemical change corresponding to the recording signals.

The phase change-type recording medium has been developed as an optical disk (postscript-type disk) on which users are permitted to record information only once or an erasable optical disk for a file memory in office use or other purposes, of which the material (inorganic or organic material) of configuration with two or more different stable states or phases of optical and/or electrical characteristics (optical transmittance, reflectance, absorption, electrical resistance or other characteristics) which generates transition from one state to another among the stable states is formed as a recording layer on a substrate by deposition or sputtering.

Other types of recording media, such as, magneto-optical, pit-forming, or bubble or irregularity-forming recording media, are also have been proposed. The recording medium provided with a charge holding layer capable of photo-modulation for recording thereon the signals carrying information as a charge image of high resolution further has been proposed.

However, there are several problems existing in the conventional recording media described above. First, large manufacturing facilities are required for forming a member of a recording layer by vacuum deposition or sputtering. Second, it is very difficult to manufacture a large number of recording media of predetermined characteristics with a high yield. Third, material used in the component in a recording layer may be poisonous. Fourth, storage reliability of a recording layer may be degraded.

Furthermore, the recording medium utilizing dislocation between crystal phases of alloy has poor absorption of heating energy and recording sensitivity. The recording medium composed of organic recording material also has poor recording responses.

The recording medium provided with a charge holding layer capable of photo-modulation, however which has difficulty in holding charges on the charge holding layer in the air for a long time.

There have further been recording medium composed of a layer of polymer dispersed with a liquid crystal, capable of electrooptically storing an image into insulating polymer matrices, and an electrode joined to, at least, one side of the layer.

Such recording medium has already been proposed by the assignee of this application, which is composed by laminating in succession a transparent electrode and the layer of polymer with liquid crystal on a transparent substrate of such as glass, or further laminating a dielectric layer on top of the polymer, or joining at least a photoconductor formed with a transparent electrode thereon, to one side of the layer of polymer with liquid crystal, when recording images. The photoconductor may be joined when manufactured.

When an image is recorded on such mediums as the layer of polymer dispersed with liquid crystal or a dielectric layer being exposed on top thereof, the image recording is performed in a way that the polymer with liquid crystal or the dielectric layer is scanned by a needle electrode carrying a voltage being made ON/OFF corresponding to the image where a bias voltage is applied between the needle electrode and the transparent electrode of the medium.

Furthermore, by means of the recording medium having a photoconductive material, image recording is performed in a way that a voltage is applied across two transparent electrodes, the photoconductive material and the layer of polymer and liquid crystal being sandwiched therebetween.

In this image recording, the image recorded on the recording medium is composed of transparent portion and non-transparent portion (where light is scattered).

However, such image thus recorded requires higher contrast ratio when the recording medium is employed as an image filter (the filter through which light is passed by the transparent portion and light is blocked by the non-transparent portion) installed into a light source and a sensitive material such as a photographic film of silver salt and diazonium sensitized paper for image exposure in an electrophotographic system or an electronic printing system or for a color filter of cyan, magenta and yellow for forming a full-coloured image.

SUMMARY OF THE INVENTION

An object of the invention is to provide an information memory medium comprising a memory layer composed of liquid crystal having molecules and a polymer member having minute pores in which the liquid crystal is contained causing the

liquid crystal having a threshold potential thereby the molecules of the liquid crystal respond to be oriented only when an applied electric field is over the threshold potential, and the molecules thus oriented are maintained after the applied electric field is removed.

Other objects and advantages of the present invention will become apparent from the detailed description to follow taken in conjunction with the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 and 2 are side views showing preferred embodiments of a recording medium according to the present invention;

Figs. 3 and 4 show recording systems for explaining recording operation to the recording medium shown in Fig. 1;

Fig. 5 shows reproduction system for explaining reproduction operation to the recording medium on which information is prerecorded shown in Fig. 1;

Figs. 6 and 7 are side views showing other preferred embodiments of a recording medium according to the present invention;

Figs. 8 and 9 show recording systems for explaining recording operation to the recording medium shown in Fig. 6;

Fig. 10 shows reproduction system for explaining reproduction operation to the recording medium on which information is prerecorded shown in Fig. 6;

Figs. 11 and 12 show characteristic of transmittance to wavelength of light of the recording medium according to the present invention, respectively;

Figs. 13 and 14 are perspective side views of still other preferred embodiments of a recording medium according to the present invention;

Figs. 15 and 16 show characteristic of transmittance to voltage of the recording medium according to the present invention, respectively;

Figs. 17 and 18 show characteristic of transmittance to wavelength of light of the other recording medium according to the present invention, respectively; and

Fig. 19 shows characteristic of transmittance to wavelength of light of a conventional recording medium.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be explained in detail with reference to accompanying drawings. Throughout the drawings, like reference numerals and letters are used to designate like or equivalent elements for the sake of simplicity of explanation.

A recording medium 10 and 10a shown in Figs. 1 and 2 respectively is composed of a base substrate 12, a transparent electrode 14 of such as ITO (Indium-Tin Oxide) and a memory layer 16 of polymer dispersed with liquid crystal, and further a dielectric layer 18 in Fig. 2.

An adequate macromolecular material is employed as the base substrate 12, such as a material through which light for reading information is passed if the recording medium is transparent-type. On the other hand, a material opaque to the light is used if the recording medium is reflection-type having a dielectric mirror allowing the light making a round excursion in the memory layer 16.

The memory layer 16 is composed by dispersing a nematic liquid crystal which behaves nematic phase at a room temperature and has high volume resistivity in the polymer such as polyester resin, polycarbonate resin, vinyl chloride resin, polyamide resin, polyethylene resin, polypropylene resin, polystyrene resin and silicon resin, each having volume resistivity 10^{14} Ωcm or more.

The dielectric layer 18 depicted in Fig. 2 also may be thin layer of macromolecular material such as polymers as described above.

Followings are the examples of formation of the memory layer 16.

(1) Nematic liquid crystal material LIXON 5017 DML (or LIXON 5028) of three grams manufactured by Chisso Co. is applied onto ten weight % chloroform solution of PMMA (Polymethylmethacrylate) of twenty grams. The solution then is stirred and left to settle.

On the other hand, a base substrate 12 coated with ITO layer as the transparent electrode 14 is sufficiently cleansed, is prepared. The chloroform solution of PMMA containing the liquid crystal material is applied onto the transparent electrode 14 by means of a bar-coater to compose the memory layer 16 of 8 micron thickness.

As for the polymer, other than PMMA described above, any polymer which can be dissolved into solution and formed into a layer and also have high volume resistivity may be used. Such as polycarbonate and PEI (Polyether Imide) having better transparency are particularly applicable for the purpose. This is also true for the example (2) described later.

The recording medium 10 shown in Fig. 1 is thus composed as above. While, the recording medium 10a shown in Fig. 2 is composed such that the dielectric layer 18 is formed on the memory layer 16 of the recording medium 10 by means of the thin layer of PMMA.

(2) Nematic liquid crystal material ZLI4277 of three grams manufactured by Merck Japan Ltd. is applied onto ten weight % chloroform solution of PMMA of twenty grams. The solution then is stirred and left to settle. Other procedures are the same as described in (1).

It is easy to form the large memory layer 16 so that the recording medium according to the present invention is adequately produced compared to conventional one.

The nematic liquid crystal used in (1) and (2) has such a high resistivity of 1×10^{13} Ωcm. Therefore, image information with high contrast ratio can be read/written from and to the recording medium including the memory layer of polymer and liquid crystal.

If the liquid crystal with low resistivity due to many ions contained. is used for the memory layer, mobility of the ions responsive to the electric field applied thereto by the charge image, lowers the intensity thereof. Inclination of the optical axis of molecules of the liquid crystal is thus decreased to degrade the contrast ratio.

However, the nematic liquid crystals used in (1) and (2) contains few ions so that undesirable phenomenon as described above does not occur. Therefore, reading/writing operation of information with high contrast ratio can be performed.

The liquid crystals in the memory layer according to the present invention are made in the state that the liquid crystal is enclosed in innumerable pores randomly distributed in the layer of porous polymer. The diameter of the pore desirably determined about 0.5 micron or less.

Any type of liquid crystal which is nematic at a room temperature with high volume resistivity and viscosity can be used for the memory layer of the recording medium according to the present invention for better quality.

Furthermore, the liquid crystal with lower melting point than that of the polymer is effective when the recording medium is composed as capable of erasing recorded information. The melting points 81.6°C of the nematic liquid crystal LIXON 5017 and 102.3°C of the nematic liquid crystal LIXON 5028 described in (1) are both lower than that of PMMA employed as the polymer.

Next information-writing operation to the recording medium according to the present invention will be explained.

Fig. 3 shows the recording system in which a voltage is applied across the transparent electrode 14 of the recording medium 10 and that 24 of a writing head 20. When an optical image of an object O is projected onto a photoconductive layer member 22 of the writing head 20, the electric resistance thereof varies accordingly with the intensity of the optical image. Then, two dimensional field intensity distribution generated between the photoconductive layer member 22 and the transparent electrode 14 is also varies correspondingly with the two dimensional intensity distribution of the optical image due to the voltage applied across the two electrodes.

Therefore, the memory layer 16 of the recording medium 10 is applied with the electric field, intensity distribution of which varies accordingly with the optical image. The nematic liquid crystal enclosed in innumerable pores randomly distributed in the polymer of the memory layer is thus oriented accordingly with the intensity of the electric field so that transparency of the memory layer is improved. The state of the liquid crystal thus oriented is not changed even if the electric field is removed.

As is described above, the memory layer is composed such that liquid crystal is enclosed in innumerable pores randomly distributed in the polymer. The liquid crystal thus contained is subject to tension caused by inner wall surface of each pore, smaller the pore, larger the tension of the wall, yet the liquid crystal in such condition exhibits nematic phase under the electric field of up to a certain threshold level. The molecules of the contained liquid crystal are oriented against such tension of the wall in response to the applied electric field of over the threshold level. And it is understood that thus oriented molecules of the liquid crystal are maintained their orientation by the tension of the wall even after the applied electric field is removed. This gives the memory layer a memory function. For better memory function, it is desirable to have pores with a diameter of 0.5 µm or less and uniformly dispersed.

Fig. 4 shows a recording system in which a signal source 30 feeds a recording electrode (needle) 32 with electric charges corresponding to analog or digital recording signals. The information is stored in the memory layer 16 as described above by applying an electric field caused between the electrodes 14 and 32 by the fed charges, the intensity distribution of the field varying correspondingly with the information to be recorded. The electrode 32 is transferred to scan the recording medium 10 when recording.

The information thus recorded can be reproduced by irradiating the recording medium with a light RL. Fig. 5 shows a reproduction system in which a light RL is projected onto the recording medium 10 and passed therethrough to be applied to a photoelectric convertor 34 which converts the light RL into electric signals.

As to reproduction, the light RL may be with large diameter to cover an entire surface of the recording medium and a two-dimensional image sensor may be employed as the photoelectric con-

vertor, or the light RL with small diameter scans the recording medium and is incident to the photoelectric convertor, or a dielectric mirror may be disposed in the recording medium so that the light RL incident thereto is reflected at the dielectric mirror and proceeds to the photoelectric convertor located other side of recording medium 10, or the light RL emitted out from the recording medium is applied to some other devices as it is not as the electric signals.

The information recorded in the recording medium is erased by heating the liquid crystal in the memory layer at the temperature higher than the melting point of the liquid crystal and lower than that of the polymer.

Namely, when the liquid crystal is heated as such the liquid crystal exhibits isotropy due to active thermal reaction of the liquid crystal having larger energy than that from the pores in which the liquid crystal is contained. And then the liquid crystal is cooled to become nematic phase. Thus recorded information is erased and the memory layer returns to be opaque.

Next, recording media 10b and 10c shown in Figs. 6 and 7 respectively includes the memory layer 16a of polymer and liquid crystal, composed by dispersing liquid crystal which is smectic at a room temperature in the polymer, instead of the memory layer 16 shown in Figs. 1 and 2.

The memory layer 16b is composed by dispersing liquid crystal which is smectic at a room temperature in the polymer such as polyester resin, polycarbonate resin, vinyl chloride resin, polyamide resin, polyethylene resin, polypropylene resin, polystyrene resin and silicon resin, each having volume resistivity 10^{14} Ωcm or more.

The memory layer 16c is produced as follows. Smectic liquid crystal S6 of three grams manufactured by Merck Japan Ltd. is applied onto ten weight % chloroform solution of PMMA of twenty grams. The solution then is stirred and left to settle. Other procedures are the same as described in (1) of production procedure of the memory layer 16b.

The polymer and other components of the recording media 10b and 10c are the same as those of the recording media 10 and 10a shown in Figs. 1 and 2.

Behaviour of the smectic liquid crystal in the polymer is the same as that of the nematic liquid crystal described before. However, the smectic liquid crystal is more viscous than the nematic liquid crystal so that higher contrast ratio is obtained in the case of reproduction from the recording media 10b and 10c.

The smectic liquid crystal with a melting point lower than that of the polymer is preferable for composing an erasable recording medium. The liquid crystal S6 described above has the melting point of about 60°C which is lower than that of the polymer PMMA.

Figs. 8 to 10 show recording/reproduction systems employing the recording medium 10b and their operations are the same as those described with reference to Figs. 3 to 5. Erasing operation is also the same. In Fig. 8, there is a gap between the photoconductive layer member 22 and the surface of the memory layer 16a, however the gap may be omitted.

Figs. 11 and 12 show the transmittance of the memory layers 16a and 16 to the wavelength of light, respectively. The curves I each depicted in Figs. 11 and 12 show the transmittance before applying an electric field to the memory layer, the curves II immediately after applying an electric field of 2.5×10^5 V/cm to the memory layer of the thickness of 8 µm which is applied with electric charges by way of corona electrical charging, the curves III in Figs. 11 and 12, 90 minutes after the application of the electric field applied to the memory layer and the curve IV in Fig. 12 the electric charge is positively neutralized 90 minutes after the application of the charge.

As is understood from Figs. 11 and 12, the memory layer 16a has better memory function and higher contrast ratio than those of the memory layer 16.

Next, recording media 10d and 10e shown in Figs. 13 and 14 respectively includes the memory layer 16b of polymer and liquid crystal, composed by dispersing a mixture of two types of liquid crystal which are smectic and nematic at a room temperature in the polymer, instead of the memory layer 16 shown in Figs. 1 and 2.

Followings are the examples of production of the memory layer 16b.

(a) Smectic liquid crystal S6 of three grams manufactured by Merck Japan Ltd. is applied onto ten weight % chloroform solution of PMMA of twenty grams. The solution then is stirred and left to settle. Nematic liquid crystal E-44 manufactured by Merck Japan Ltd. is also processed in the same manner as the liquid crystal S6. Both solutions of smectic and nematic liquid crystals are mixed with each other in weight ratio of 10 to 20 : 1 and the solution thus mixed is stirred and left to settle. The surface of a transparent electrode 14 formed on a base plate 12 is sufficiently cleansed, is prepared. Then, the mixed solution is applied onto the transparent electrode 14 by means of a bar-coater to consequently form the memory layer of 8 micron thickness.

(b) Smectic liquid crystal S6 is processed in the same way as described in (a). Nematic liquid crystal ZLI 3976 of three grams manufactured by Merck Japan Ltd. is applied onto ten weight % chloroform solution of PMMA of twenty grams. The

solution then is stirred and left to settle. Both solutions of smectic and nematic liquid crystals are mixed with each other in weight ratio of 10 to 20 : 1 and the solution thus mixed is stirred and left to settle. Other procedures are the same as described in (a).

The polymer and other components of the recording media 10b and 10c are the same as those of the recording media 10 and 10a shown in Figs. 1 and 2.

Figs. 15 and 16 show the transmittance of the memory layer 16b and 16 to the voltage applied thereto, respectively. As is obvious from Figs. 15 and 16, the curve for the memory layer 16b starts to rise at about 150 V while about 250 V for the memory layer 16. This means that the memory layer 16b requires less voltage to be operated than the memory layer 16.

When it comes to change of the transmittance of the memory layer when an electric charge is applied thereto then neutralized, the memory layer 16 has a transmittance change of about 70% while the memory layer 16b about 90%. This results in resolution and contrast ratio being improved if the memory layer 16b is employed.

In general, the nematic liquid crystal is not so viscous that orientation of its molecules reduces as time lapse. However, the nematic liquid crystal requires rather low voltage to be operated. While, the smectic liquid crystal is so viscous that orientation of its molecules is preferably maintained. Thus the smectic liquid crystal has better memory function. However, this liquid crystal requires high voltage to be operated.

Accordingly, when more nematic liquid crystal is mixed with the smectic liquid crystal, the voltage is lowered, whereas, memory function of the smectic liquid crystal is degraded. The weight ratio 10 to 20 : 1 for mixing the liquid crystals with each other results in preferable transmittance as shown in Fig. 15.

Contrast ratio will be improved by employing the nematic liquid crystal having relatively higher refraction index and anisotropy. Furthermore, liquid crystal which is smectic or nematic at a room temperature is employed in the embodiments, the present invention is applicable at any other temperature by employing optimum liquid crystal depending on the temperature.

Recording, reproduction and erasing operations are the same as those described previously.

Followings are other examples of production of the memory layer.

(c) Smectic liquid crystal S6 of three grams manufactured by Merck Japan Ltd. is applied onto ten weight % chloroform solution of PMMA of twenty grams. The solution then is stirred to be a liquid A. Then, a thin layer of ITO (a transparent electrode) is formed on a transparent substrate. The thin layer is sufficiently cleansed and then coated with the liquid A by means of a bar coater and dried. The layer of polymer and liquid crystal having a thickness of 8 µm is formed on the transparent electrode to compose a recording medium V. The recording medium V is then heated to about 60° C or more in which the layer of polymer and liquid crystal becomes isotropic to be transparent and then gradually cooled down to compose a recording medium W.

(d) Nematic liquid crystal E-44 of three grams manufactured by Merck Japan Ltd. is applied onto ten weight % chloroform solution of PMMA of twenty grams. The solution then is stirred to be a liquid B. The liquids B and A are mixed with each other in the ratio of 10:1 to 15:1. Other procedures are the same as those described in (c) to produce a recording medium X. The recording medium X is heated and then cooled down in the same manner as described in (c) to be a recording medium Y.

To the recording media V, W, X and Y, transmittance (I) in visible range in which light passes through the layer of polymer and liquid crystal immediately after manufactured and before applied with an electric charge, transmittance (II) in visible range applied with an electric charge of 2.5×10^5 V/cm, and transmittance (III) in visible range applied with that electric charge which is subsequently neutralized are measured. The electric charge applied to the layer is generated by way of corona electrical charging and positively neutralized by reverse corona electrical charging.

According to the measuring, curves shown in Fig. 17 are obtained for the recording media W and Y, and those shown in Fig. 18 for the recording media V and X.

There is another recording medium including the same nematic liquid crystal as above. When the same measurements as above are performed to this recording medium, the result is as shown in Fig. 19. It is found when the results in Figs. 17 and 19 are compared with each other that the contrast that is the difference of transmittance at each wavelength between the curves I and II and those I and III particularly at a longer wavelength, is large.

Next, memory function is evaluated (the smaller the change of the curve III as the time elapse, the better the memory function) by measuring the change of the curve III in which the recording media are made transparent by applying an electric charge thereto and then are subsequently neutralized. The curves III in the respective figures indicate the response when 90 minutes have passed from the neutralization. It is found that the curves III barely vary in the recording media as shown in Figs. 17 and 18. While it largely varies in

the recording medium including nematic liquid crystal as shown in Fig. 19. This results in the recording media V, W, X and Y having better memory function.

Throughout the preferred embodiments according to the present invention as described in the foregoing, the configuration of the recording medium, particularly that of an electrode depends on the method of image recording.

Namely, in the case of the recording by means of a needle electrode, the recording medium is configured as such that the recording layer of polymer containing liquid crystal or a dielectric layer coated over the recording layer is exposed and a flat electrode is laminated to the recording layer. The flat electrode may be transparent or not.

In the case of the recording by selectively applying a voltage across each dot of dot matrix electrodes and a flat electrode, the recording medium is configured as such that the recording layer is sandwiched between the two electrodes at least when the recording is performed, and either one of the electrodes is transparent and supported by a transparent substrate.

Furthermore, in the case of the recording by combination of uniform electric charge and an image exposure to the layer of polymer and liquid crystal, the recording medium is configured as such that a photoconductive layer is contacted to a dielectric layer coated over the recording layer or contacted directly to the recording layer. When the photoconductive layer is used to receive the uniform electric charge, one side of the photoconductive layer is configured to be exposed. When the photoconductive layer is used to be applied with a voltage to generate a uniform electric field over the recording layer, a flat transparent electrode supported by a transparent substrate if needed, is laminated to one side of the photoconductive layer.

If the photoconductive layer, attached to a side of the recording medium, is made transparent, the other side of the recording medium is attached with a transparent flat electrode which may be supported by a transparent substrate laminated thereto.

As for the material of the electrode, a well known material, such as the vacuum evaporation-layer or sputter-layer of SiO_2 and In_2O_3 (ITO), etc., is employed. A metal such as aluminium is added to that if the electrode does not need to be transparent. Then the electrode is formed by vacuum evaporation and sputtering, etc.

As for the photoconductive layer, normally, the material having volume resistivity of 10^{14} Ωcm or more when not exposed to light and 10^{12} Ωcm or less when exposed is employed.

Such materials for the photoconductive layer are as follows: a single material layer of such as Se or SeTe, or a photoconductive particles dispersed type in which photoconductive particles made of an inorganic pigment such as CdS exhibiting photoconductivity to light or an organic pigment such as phthalocyanine and quinacridone pigment is dispersed in the polymer, a dye sensitization type in which sensitizing dyes are dispersed or dissolved in photoconductive polymer such as polyvinyl carbazole, a laminated type in which a charge generating layer is laminated to a charge transfer layer for transferring charges generated from the charge generating layer. Such charge generating layer may be composed of thin film of Se or SeTe having a thickness of 1 micron or less, or composed of macromolecular matrix comprising aforementioned pigment or dye, or photoconductive polymer containing such pigment or dye, and such charge transfer layer may be composed of similar materials dispersed or dissolved into the same polymer as mentioned before. Such photoconductive layers can be produced by known methods.

Claims

1. An information memory medium, comprising: a memory layer composed of liquid crystal having molecules and a polymer member having minute pores in which the liquid crystal is contained causing the liquid crystal having a threshold potential thereby said molecules of the liquid crystal respond to be oriented only when an applied electric field is over the threshold potential, and said molecules thus oriented are maintained after the applied electric field is removed.

2. An information memory medium according to claim 1 wherein the liquid crystal has lower melting point than that of the polymer member.

3. An information memory medium according to claim 1 wherein the polymer member has volume resistivity of 10^{14} Ωcm or more.

4. An information memory medium according to claim 1 wherein the liquid crystal is smectic at a room temperature.

5. An information memory medium according to claim 4 wherein the liquid crystal has lower melting point than that of the polymer member.

6. An information memory medium according to claim 1 wherein the liquid crystal is a mixture of liquid crystals which behave smectic and nematic phases respectively at a room temperature.

7. An information memory medium according to claim 6 wherein the liquid crystal has lower melting point than that of the polymer member.

8. An information memory medium according to claim 2, wherein said liquid crystal is in isotropic phase by being heated below said melting point of the polymer member.

9. An information memory medium according to claim 1, wherein an electrode in a form of plane is laminated to only one side of said memory layer.

10. An information memory medium according to claim 9, wherein said electrode is sandwiched between said memory layer and a substrate supporting said electrode.

11. An information memory medium according to claim 10, wherein said substrate is transparent.

12. An information memory medium according to claim 1, wherein a photoconductive layer is further contacted directly to said memory layer for recording optical information.

13. An information memory medium according to claim 1, wherein said memory layer is coated with a dielectric layer and a photoconductive layer being contacted thereto for recording optical information.

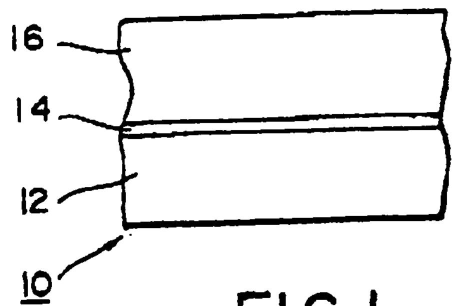


FIG. 1

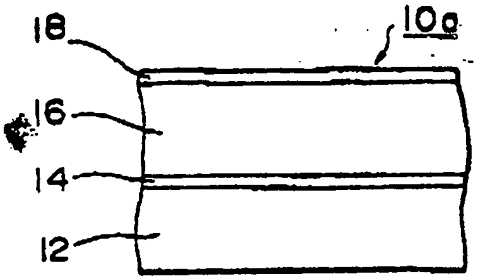


FIG. 2

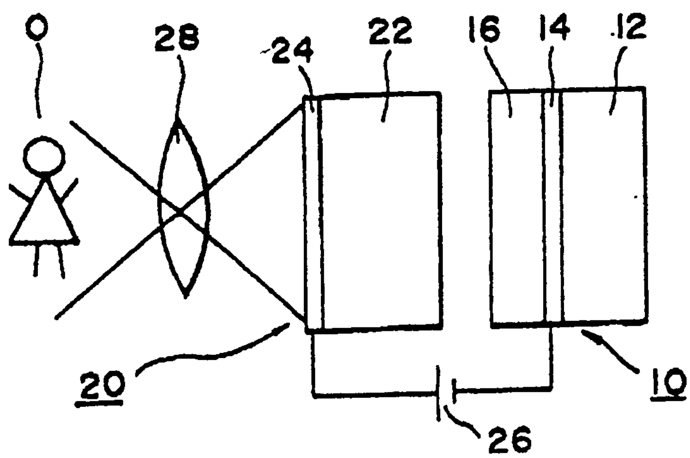


FIG. 3

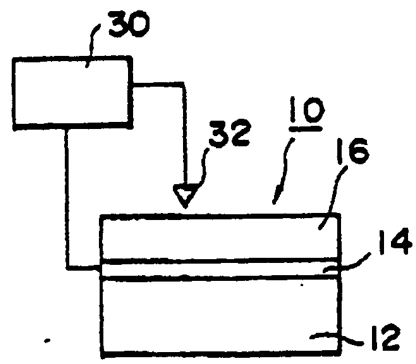


FIG. 4

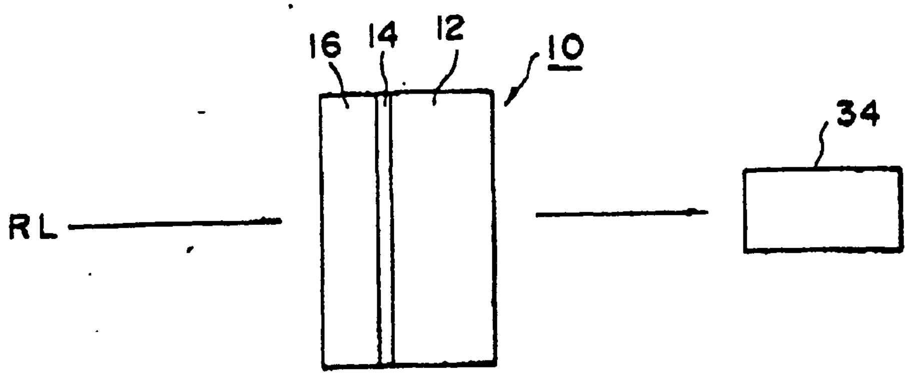


FIG. 5

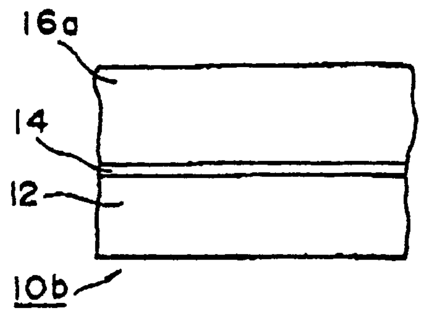


FIG.6

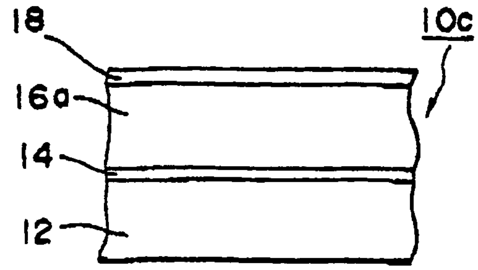


FIG.7

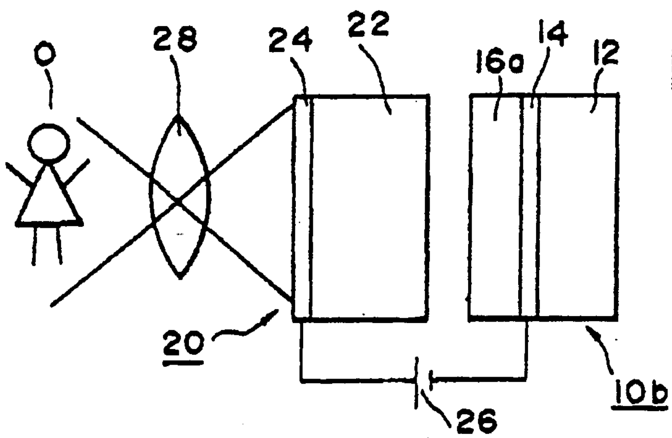


FIG.8

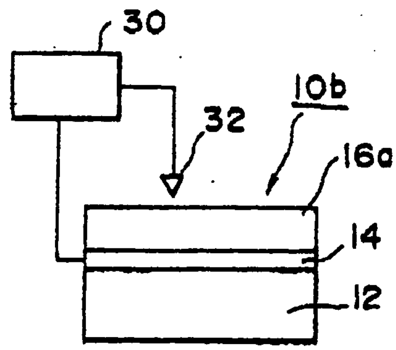


FIG.9

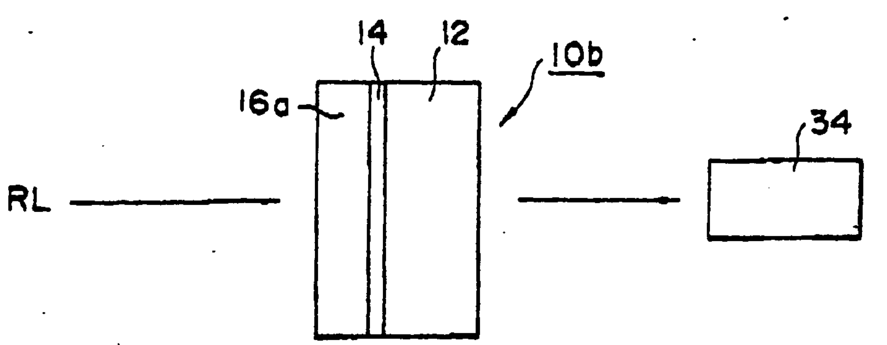
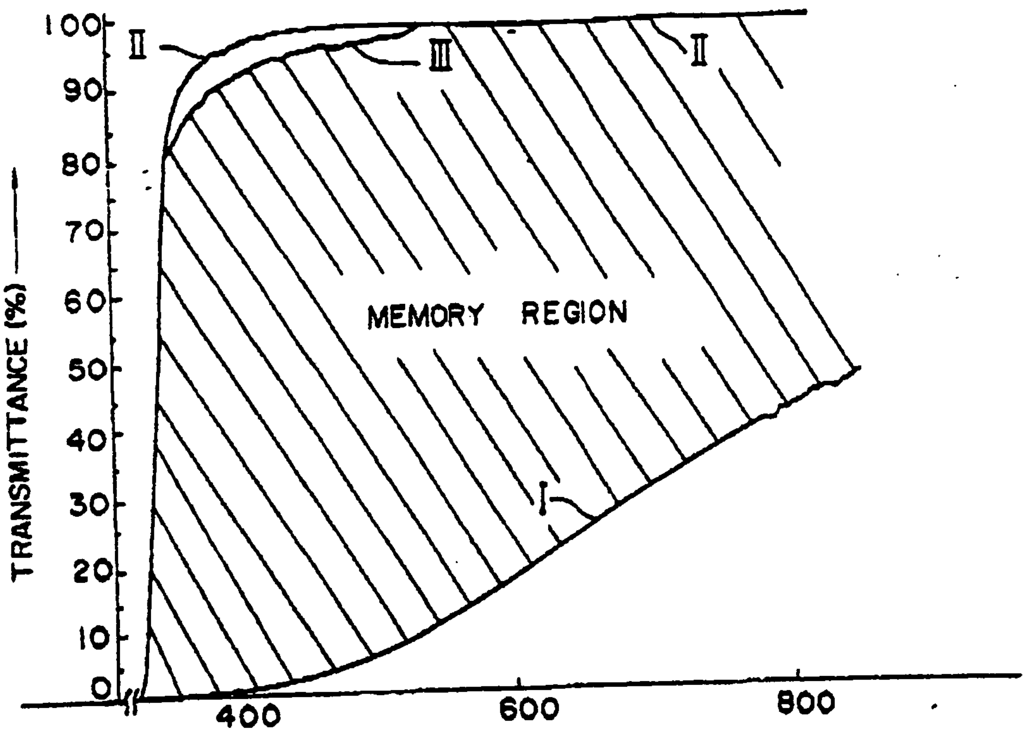
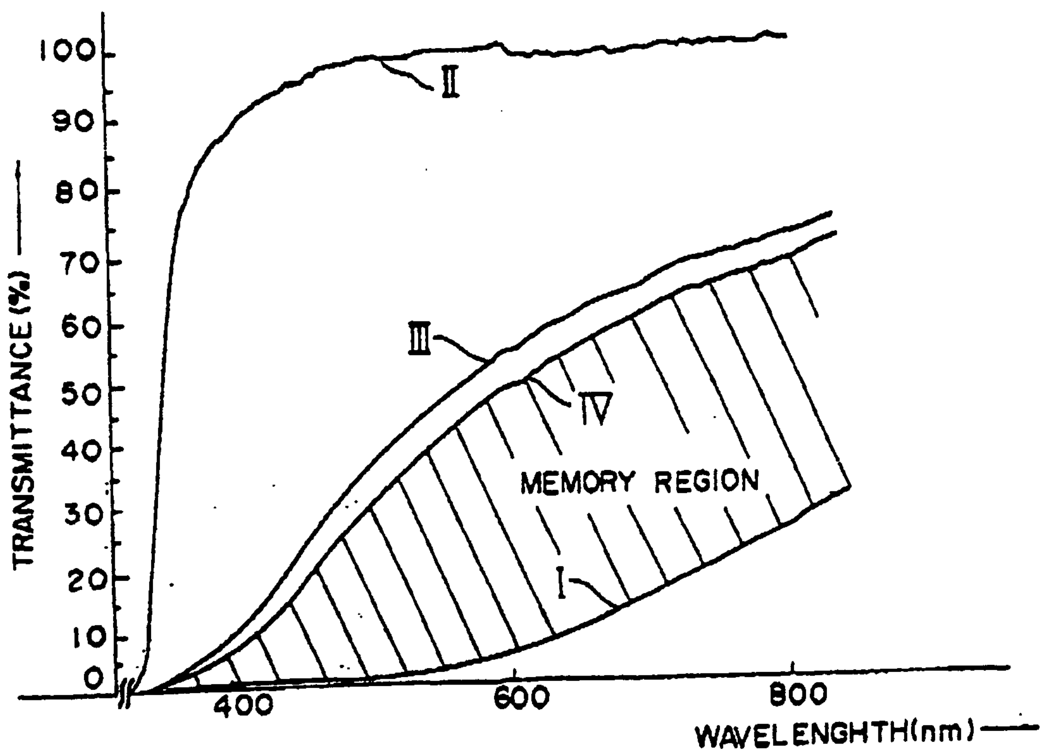


FIG.10



100
90
80
70
60
50
40
30
20
10
0
TRANSMITTANCE (%)
II
III
II
MEMORY REGION
I
400
600
800
WAVELENGTH(nm)

FIG.11



100
90
80
70
60
50
40
30
20
10
0
TRANSMITTANCE (%)
II
III
IV
MEMORY REGION
I
400
600
800
WAVELENGHTH(nm)

FIG.12

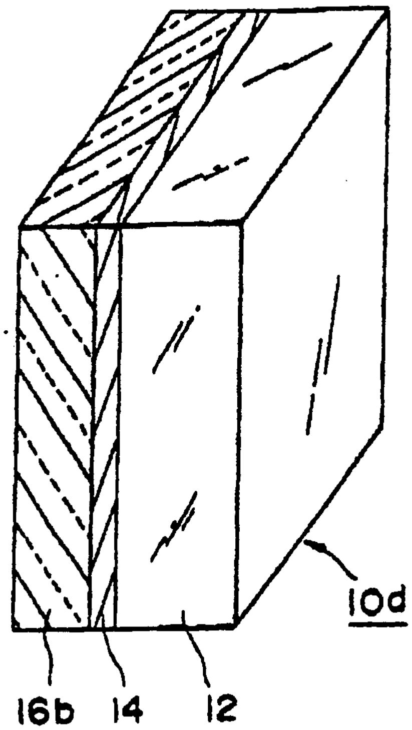


FIG.13

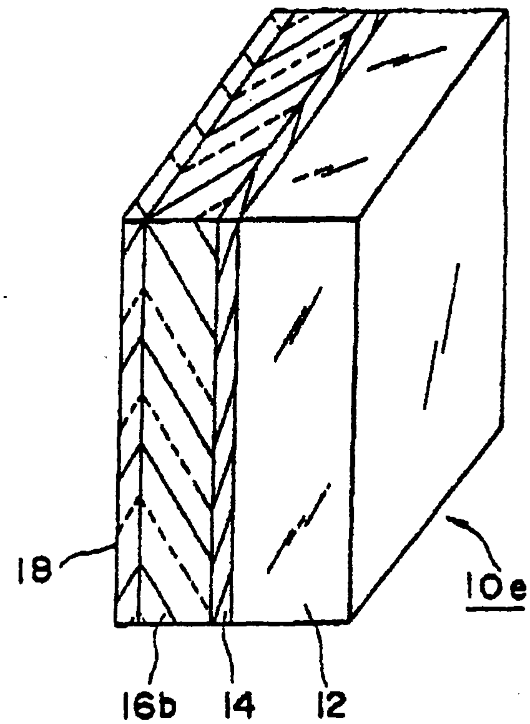


FIG.14

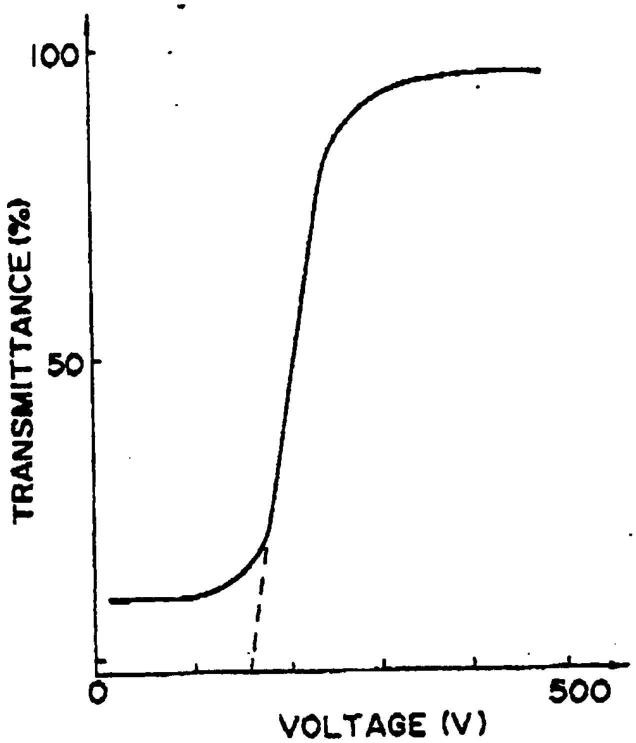

100
50
TRANSMITTANCE (%)
0
500
VOLTAGE (V)

FIG.15

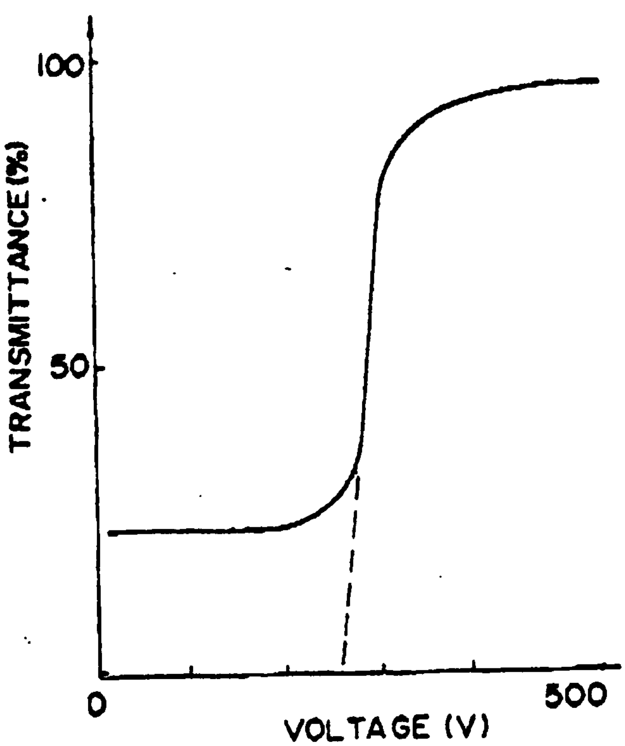

100
50
TRANSMITTANCE (%)
0
500
VOLTAGE (V)

FIG.16

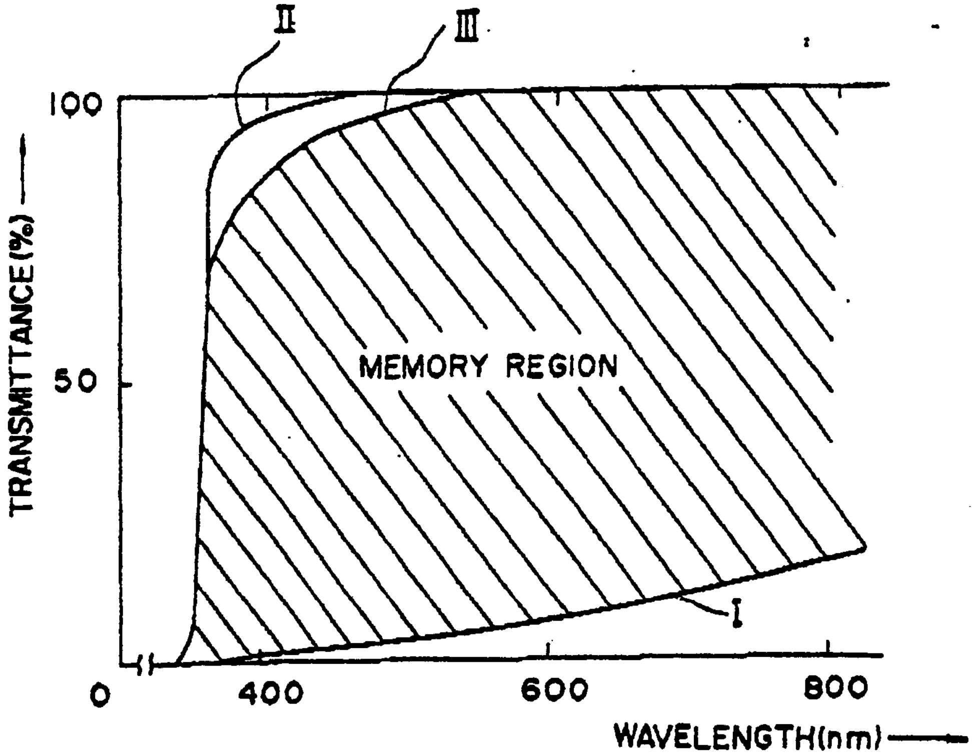

II
III
100
50
0
TRANSMITTANCE(%)
MEMORY REGION
I
400
600
800
WAVELENGTH(nm)

FIG.17

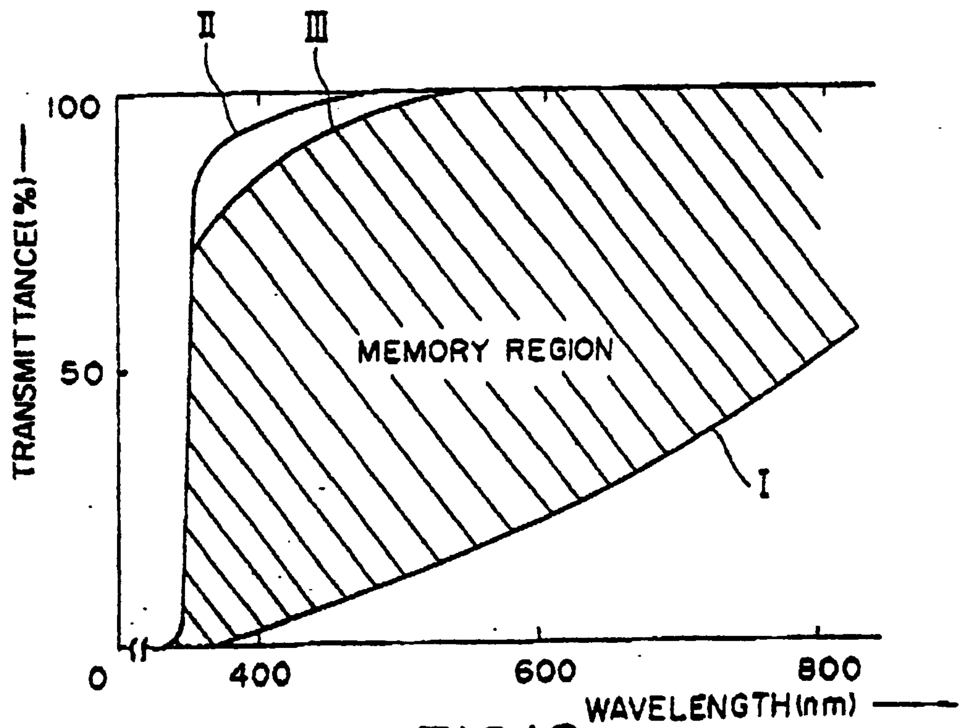

II
III
100
50
0
TRANSMITTANCE(%)
MEMORY REGION
I
400
600
800
WAVELENGTH(nm)

FIG.18

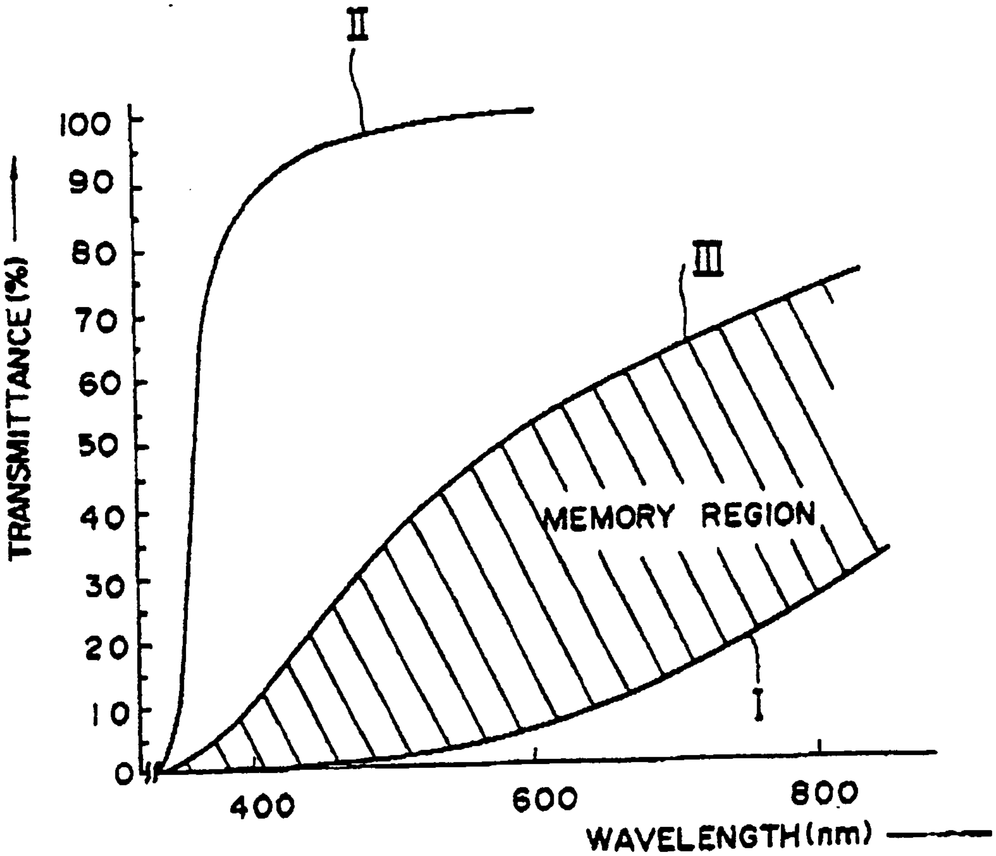

II
III
MEMORY REGION
I
TRANSMITTANCE (%)
100
90
80
70
60
50
40
30
20
10
0
400
600
800
WAVELENGTH (nm)

FIG.19